Arbitrage between the spot and futures markets for eurodollars(1)

This article examines whether the futures market for eurodollars in London operates efficiently, in the sense that prices adjust so as to eliminate opportunities for profitable arbitrage between the spot and futures markets. Statistical analysis is reasonably conclusive in giving an affirmative answer. The article also describes how neither interest rates available on the futures market nor implied forward rates derived from the spot market provide precise measures of current market expectations of future spot interest rates, because liquidity and risk considerations influence behaviour in these markets. Such considerations help to explain the relationship between prices in the two markets.

Introduction to financial futures

A futures contract is a binding agreement to deliver, or receive, a given quantity and quality of a commodity at an agreed price on a specified date. Futures contracts have existed from at least as early as 1730, when in Japan forward contracts for rice on the Osaka Rice Exchange were formally recognised. A financial futures contract is an agreement to buy or sell a standard quantity of a specified financial instrument at some future date, at a price agreed between the parties. Generally, such contracts are traded on formal futures exchanges where, typically, the financial instruments which can be traded, the standard quantities (or units of trading) of each contract, the future settlement dates, margin requirements and associated regulations are prescribed.

The earliest financial futures were foreign currency contracts which were first traded in the United States on the International Commercial Exchange in 1970. Interest rate futures were also an American innovation, the first contracts being traded on the Chicago Board of Trade in 1975. The London International Financial Futures Exchange (LIFFE) opened in September 1982 and initially traded four contracts in currency (exchange rate) futures and three in interest rate futures. The latter have proved the more popular range, probably because the long-established forward foreign exchange market offers a product similar to, albeit less standardised than, currency futures. Since September 1982, three more futures contracts and two options contracts have been introduced in London. The growth of total turnover of futures contracts traded on LIFFE since its inception is shown in Chart 1. Turnover of the three-month eurodollar contract is identified separately because it is now the most heavily traded contract, comprising 34% of total turnover in the third quarter of this year (Chart 2).

Chart 1
LIFFE: turnover

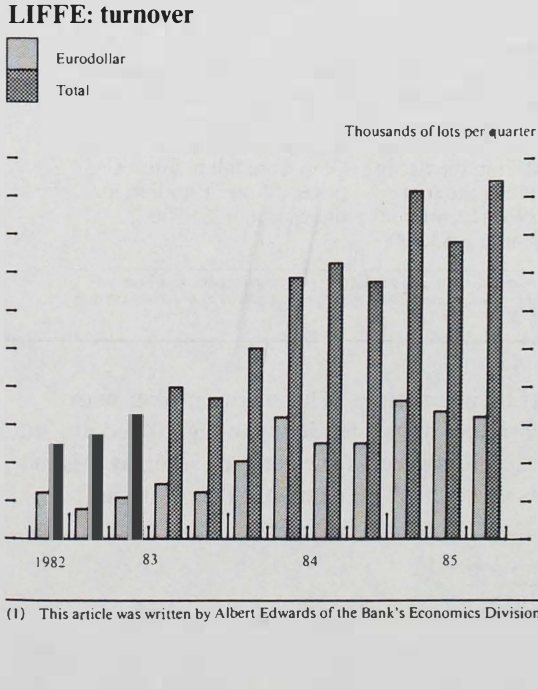
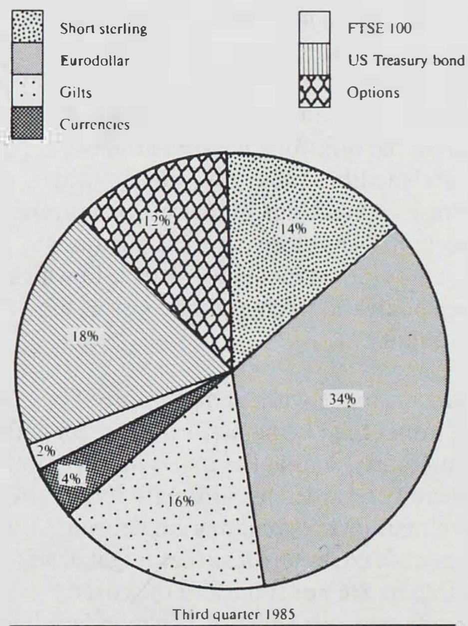


Chart 2
LIFFE: turnover
Percentage of total lots



The main purpose of a financial futures contract is to enable participants to fix in advance the interest or

(1) This article was written by Albert Edwards of the Bank's Economics Division.

exchange rates that will apply to their transactions at specified times in the future. This allows them to avoid the risk of adverse rate movements in the spot market, or to speculate on such movements. For instance, a borrower may hedge against a possible rise in interest rates, which would otherwise increase the cost of servicing a floating-rate loan or the prospective cost of a fixed-rate loan to be contracted in the future. (The box on this page presents a simple example of hedging by a company which is due to roll over a loan but is worried that interest rates may rise.)[1]

Although at the time interest rate futures began trading in London there was no rival market offering a similar forward product,[2] it has always been possible to use the spot market to secure some protection against future interest rate movements. For instance, a company which borrows at fixed rates for six months and deposits the proceeds for the first two months is effectively borrowing 'forward' in two months' time for a period of four months. However, such a strategy has a number of disadvantages compared with a financial futures contract. The buildup of liabilities and assets extends the balance sheet and may adversely affect measures of company performance that do not take account of the offsetting nature of the two spot transactions; and facilities to borrow may anyway be limited. In contrast, transactions in interest rate futures are 'off balance sheet'; hedgers close out their positions before taking delivery of the financial instrument in which they are dealing (see box); and the margin deposit is the only call on their liquidity.

Every futures contract is made with, and guaranteed by, the clearing house, rather than being performed direct with any particular counterparty, so that the risk is uniform to all traders (and generally regarded as minimal). Every trader is required to maintain a small margin deposit, calculated as sufficient to cover any loss that might arise from default, and traders are not subject to the costs implicit in the bid-offer spreads which they would face if hedging through the spot markets. In sum, the futures market offers a highly standardised product, in format, risk and direct costs. Moreover, the centralisation of the market eliminates the indirect costs of searching for counterparties, which may arise in the spot market. Of course, features which are attractive to some may not be so to others: for instance, someone able to command the finest spreads in the spot market, or not wanting to be constrained to deal for the specific contract dates set by the futures exchange, may prefer to hedge through the spot market, or nowadays by forward rate agreements. However, the futures market undeniably meets a particular set of needs in the spectrum of demand for financial services.

One of the main factors holding back the development of financial futures in London has perhaps been general ignorance of their functions. Those not familiar with hedging techniques have a tendency to regard hedging via futures markets as a speculative activity, whereas it is in fact a means to establish an element of certainty in

Example of interest rate hedging using the futures market

On 1 August a company borrows $1 million on the eurodollar market for three months at 10% per annum. This borrowing is scheduled to be rolled over on 1 November. The company, worried that rates may have risen by then, sells a December $1 million eurodollar three-month futures contract at a price of 89.00 in order to lock into currently available interest rates, specifically 11% for the three months beginning in December. (This happens to be 1 percentage point above the current rate on the spot market.) By 1 November when the firm rolls over the $1 million loan, the current rate of interest has risen to 12%. The company rolls over its borrowing at this rate but also buys a December three-month eurodollar futures contract at a price (assuming the interest rate on the futures contract has remained at one percentage point above the spot rate) of 87.00. This second futures transaction is called 'closing out' the previous position in the market. The two futures deals together yield a profit of $5,000 (2% of $1 million for three months), exactly offsetting the extra cost incurred in the spot market because of the rise in interest rates. In other words, the net cost at which the borrowing is being rolled over is 10%.

Cash market	Futures market
1 August	
Company takes $1 million loan at current spot interest rate of 10%, planning to roll it over on 1 November	Sells one $1 million December three-month eurodollar deposit futures contract at a price of 89.00[1] (rate = 11%).
1 November	
Company rolls over loan at the new spot interest rate of 12%.	Buys a $1 million December futures contract at the new price of 87.00 (rate = 13%).
Extra cost from the rise in interest rate in the spot market: 2% on $1 million for one quarter = $5,000.	Gain from fall in futures price: 2% on $1 million for one quarter = $5,000

(1) The three-month sterling and eurodollar interest-rate contracts are quoted on an index basis. The annual interest rate is calculated by deducting the price from 100.

(1) A LIFFE publication entitled 'Hedging Techniques' gives more sophisticated examples of how to hedge interest rate risks.

(2) In the last two years a number of banks have begun trading forward rate agreements in interest rates. These are similar to futures contracts in that two parties agree an interest rate for a specified period of time for a future settlement date, but trading is not standardised and is conducted bilaterally rather than through an exchange. The volume of such trading has to date been smaller than that on the financial futures market.

future deals, in place of risk. Of course speculators are also present in the futures market; indeed their presence is vital to provide the liquidity that is required to enable hedgers to take and close positions with ease.

Hedging via the spot market

As already noted, one means by which hedgers may be able in effect to fix an interest rate for a future transaction is to borrow and lend simultaneously for different periods at fixed rates on the spot market. The future rate thus obtained is known as the implied forward rate. The implied forward rate for, say, borrowing for four months in two months' time can be derived from the present levels of two-month and six-month rates. More generally, implied forward rates are determined by the shape of the yield curve (also known as the term structure of interest rates). (See appendix.)

The basic theory of the term structure of interest rates is the pure expectations theory. This theory, which can be attributed to Fisher (1930), relates the implied forward rate to expected future spot rates.[1] If, to take an example from bond markets, an investor has funds to place for two years and considers that the market's present implied forward rate for investing for one year in one year's time is below his own expectation of interest rates one year hence, he will buy a one-year bond now, and another a year from now. If other investors now adopt similar expectations, holders of two-year bonds will sell in favour of one-year bonds, causing yields on two-year bonds to rise and those on one-year bonds to fall. The implied forward rate for one year hence will rise. This process will continue until the implied forward rate is consistent with the revised market expectations. In this way the shape of the yield curve reveals important information regarding market expectations of the future level of interest rates.

Scope for arbitrage between spot and futures markets

The existence of a financial futures market allows futures rates to be observed directly. An individual trader may find that the currently quoted futures interest rate is different from his own expectation of the future levels of that interest rate. He will buy or sell futures contracts based on his estimation of whether they are relatively cheap or dear. In aggregate, the futures rate will be driven to a level which is indicative of (though not, as explained later, identical with) the market's expectation of the future level of that interest rate.

In the absence of transactions costs or other market imperfections in the futures and spot markets, the implied forward rate and the futures rate should be identical, both being based on all information currently available to traders. If they are not equal, arbitrageurs can make riskless gains. For example, if the implied forward rate is significantly below the corresponding futures rate, profits can be made by simultaneously borrowing long and depositing short in the spot market and buying a futures contract. This process would tend to induce price or rate movements which would close the gap between the implied forward rate and the futures rate.

In practice, transactions costs cannot be ignored. In the spot market such costs typically arise in the form of bid-offer spreads, so that, instead of one implied forward rate, there are two—one for borrowing and one for depositing. If the futures rate lies outside this range, one would expect arbitrageurs to operate between the two markets, moving prices until riskless profits were no longer available.

If, given interest rates in the spot market, systematic arbitrage gains are available through the futures market, the latter may be regarded as inefficient, in the sense of violating what is known technically as the 'weak form of market efficiency'. A market satisfies the weak form of market efficiency if currently quoted prices fully reflect all publicly available information of historical prices as well as current prices data from other markets. If the market is efficient in this sense, it should not be possible to devise a strategy that would yield riskless profits.

Have persistent arbitrage profits been available?

This section investigates the availability of profitable arbitrage opportunities in the context of the most active financial futures contract in London, namely the three-month eurodollar deposit contract.

The analysis follows a framework which is very similar to that which has been used in American studies of the thirteen-week US Treasury bill futures contract.[2] The American authors construct upper and lower bounds defined by the bid-offer spread of the implied forward rate, explicitly taking into account any transactions costs.

Upper and lower arbitrage bounds were calculated for the forward depositing and lending of three-month eurodollar funds in accordance with the procedure set out in the appendix. For no arbitrage opportunities to exist, futures prices should be within these bounds.

The results for the successive eurodollar deposit contracts traded since the opening of LIFFE in September 1982 are given in the table and charts on pages 565–8. The table details the number of days on which the futures rate lay within the arbitrage band or above the upper bound; on no occasions was the futures rate found to be beneath the lower bound. Following Lang and Rasche (1978), the table also shows the number of occasions on which the futures rate was within the band or 'close' to it (defined as

(1) Expected future spot rates are the spot rates which are currently expected to pertain at some future date. These may, for reasons explained in this article, not necessarily be the same as futures rates currently observable on the futures market or implied forward rates derived from the yield curve.

(2) Branch (1978), Capozza and Cornell (1979), Lang and Rasche (1978), Poole (1978), Puglisi (1978), Rendleman and Carabini (1979), Vignola and Dale (1979).

within 0.10 of a percentage point beyond either bound).[1] The arbitrage band and corresponding futures rates (depicted by the continuous line) for each eurodollar contract are charted through the respective periods before delivery.

Since the opening of LIFFE, the contracts nearest to delivery have displayed the strongest tendency for the futures rate to lie within the arbitrage band.[2] On the basis of the test statistics recorded in the table it can be concluded that all twelve contracts that have so far been traded satisfy statistically the hypothesis that, when they are the contract nearest to delivery, the futures rate is not significantly different from the mid-point of the arbitrage band. In addition, six of these contracts have futures rates that are significantly below the upper arbitrage bound.

In contrast, when the contracts are further from delivery, the futures rates tend to be significantly above the mid-point of the arbitrage band. For the most part, these futures rates do not tend to lie significantly below the upper bound, although there is no tendency to lie significantly above it.

Over the last three years, there has been a tendency for the pricing of futures contracts to become more efficient. From the charts it can be seen that, for contracts that have matured recently, futures rates have tended to lie closer to the middle of the arbitrage band. This hypothesis is supported by the result that three out of the last four contracts had futures rates which were not significantly different from the mid-point of the arbitrage band while they were the second nearest contract to delivery. This tendency towards more efficient pricing contrasts with the results of work by Rendleman and Carabini (1979). They found that the thirteen-week US Treasury bill futures contract traded on the Chicago Mercantile Exchange that was closest to delivery had tended to become less efficient over the two-year period examined.

As a whole, the results show that systematic arbitrage gains have not been available in the three-month eurodollar futures contract since its introduction in September 1982. In spite of the apparent availability of arbitrage profits on a few days, such gains would probably have been negligible after taking account of less explicit costs. It can be concluded that this contract has satisfied the 'weak form of market efficiency'. One subsidiary feature of note is that futures rates have tended towards the upper arbitrage bound, except when the delivery date approaches.

An explanation for bias in the relationship between futures and implied forward rates

Hicks (1946) argued that the pure expectations theory, described earlier, required qualification. Following Keynes' (1930) ideas on commodity futures markets, Hicks suggested that the yield curve contained a liquidity premium, which caused implied forward rates to be upwardly-biased measures of market expectations of future spot interest rates. This, he argued, was due to a weakness in the long side of the spot market: many borrowers needed funds over extensive periods, exhibiting therefore a strong propensity to borrow long to ensure a steady availability of funds. Hicks conjectured that lenders had no such offsetting propensity, so that a premium had to be paid by borrowers to lenders to induce them to lend long. Thus, on this view, even when future interest rates are expected to be equal to current rates, the yield curve will slope upwards with long rates exceeding short rates.

In support of Hicks, empirical research by Hamburger and Platt (1975) on the efficiency of the US Treasury bill market noted an upward bias in implied forward rates as measures of future spot interest rates. In earlier work, Kessel (1965) found that adjusting implied forward rates for liquidity premia produced better indicators of eventual spot rates.

Poole (1978) examined arbitrage possibilities of the contract closest to delivery. He thought that if implied forward rates (and hence the arbitrage bounds) were upwardly biased measures of expected future interest rates due to liquidity premia, whereas futures rates were unbiased, one would expect futures rates to tend towards (but not below) the lower arbitrage bound. Poole's results supported this hypothesis, leading him to conclude that thirteen-week US Treasury bill futures were good indicators of expected future interest rates.

Other work in the United States has examined contracts in addition to the one nearest delivery. The findings are that for contracts other than that nearest to delivery there is a definite tendency towards the upper arbitrage bound. Lang and Rasche (1978) suggested that there might be a default risk in the futures market which did not exist in the spot market (the counterparty to a futures contract might default, whereas the US Treasury would not), but this idea seems implausible in the light of the clearing house arrangements, and in any event could not be generalised as an argument in the eurodollar market. Others suggested that the futures and spot Treasury bill markets were not fully integrated (Branch 1978), or that the existence of start-up costs for entry into the futures market (Capozza and Cornell 1979) hindered arbitrage activity and prevented the efficient pricing of futures contracts.

It may, however, be possible to explain the results of the present study and of the earlier American research by combining Hicks' ideas on liquidity premia with Keynes' ideas explaining 'normal backwardation', from which Hicks' theory originated. Keynes in his theory of 'normal

(1) This makes some allowance for other costs (eg dealers' time) and is equivalent to $250 on the standard $1 million contract.
(2) A futures contract is delivered at dates specified by LIFFE. For the three-month eurodollar deposit futures contract, delivery days are the second Tuesday of March, June, September and December. At any one time the futures contract currently traded with the next delivery date is termed nearest to delivery. This study examines contracts from the time they become the third nearest to delivery until delivery.

backwardation' viewed speculators as insurers, receiving a risk premium from the hedgers. Deriving his theory by reference to commodity markets, Keynes postulated that in normal conditions hedgers were likely to be net sellers of futures contracts. The futures price would then be less than the expected spot price by the amount the hedger was willing to sacrifice to avoid the risk of price fluctuations. This premium would be the larger the more distant was the delivery date. If, as is generally believed to be the case, the same is true of financial markets, that is, if borrowers are more likely to seek to hedge than are lenders, one may expect futures rates themselves to be upwardly-biased measures of expected future spot interest rates.

Keynes' and Hicks' theories suggest that both the futures and implied forward rates are upwardly biased measures of expected future spot rates. The tendency for futures rates to lie towards the upper arbitrage bound for contracts further from delivery suggests that the Keynesian risk premium may be more important than the Hicksian liquidity premium. The relative size of these premia is partly due to the number of hedgers and speculators in each market. Hedgers may predominate in the futures market on contracts further from delivery for two reasons. Hedgers who are not prime names may find it difficult to borrow over long periods at fixed rates of interest that they can afford. They may therefore prefer or be obliged to use the futures market. Secondly, speculators in the futures market tend to be more willing to trade contracts that are closer to delivery, since their expectations will tend to be better defined for short periods ahead. The concentration of hedgers relative to speculators in futures contracts further from delivery will tend to increase the risk premia required to induce speculators to enter into an agreement. Since no similar tendency exists in the spot market, the upward bias of futures rates (as measures of expected future spot rates) will tend to be greater than the bias of implied forward rates. For short periods ahead, however, both markets are likely to contain similar numbers of hedgers relative to speculators, so that Keynes' risk premium and Hicks' liquidity premium will be of similar magnitude, causing futures rates to lie close to the middle of the arbitrage band.

Conclusion

Futures rates in the LIFFE eurodollar contract appear to correspond closely to implied forward rates, closeness being defined by the extent of transactions costs. The consequent absence of opportunities for systematic arbitrage gains suggests that the LIFFE market in this contract satisfies the weak form of market efficiency. Interest rates observed in the futures market and those derived from spot markets are both thought to be upwardly biased measures of market expectations of future interest rates. The relative size of the bias helps to explain why, for contracts further from delivery, futures rates tend to lie towards the upper arbitrage bound.

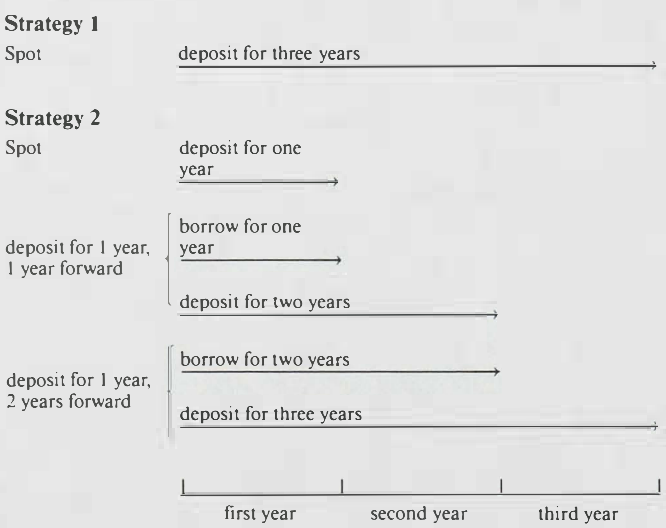
Appendix

Implied forward rate

The implied forward rate is given by—

$$1 + (L-S).r_F = \frac{(1+L.r_L)}{(1+S.r_S)} \quad \text{for } S<L \qquad (1)$$

where r_F is the implied forward rate on a L–S period loan (deposit) to be transacted at a future date S periods ahead, r_L is the spot rate for a L period loan (deposit) and r_S is the spot rate on a S period deposit (loan).[1] At any point in time a complete set of spot rates (usually called the yield curve) provides the basis for calculating a series of implied forward rates. These rates are by definition such that, disregarding transaction costs and risk premia, an investor with funds to place for n periods would obtain the same rate of return from making one n-period deposit as from a single one-period deposit plus n–1 forward, consecutive one-period deposits. The strategies are identical, as the diagram shows for the example of a three-year deposit: although the second strategy involves five transactions, the first four cancel.



Arbitrage bounds

The upper and lower arbitrage bounds are an extension of equation 1. The upper bound is defined as the implied forward borrowing rate, F^u, where—

$$[(1-M)(1+S.r^d_S)+M]\,(1+(L-S).F^u) = (1+T)(1+L.r^b_L) \qquad (2)$$

On the right hand side of the equation, the arbitrageur today borrows, for L periods, one unit plus any transaction costs (T) to be incurred in the futures market, at an annualized interest rate of r^b_L. The arbitrageur then purchases a 90-day futures contract to be delivered in S periods time. Transaction costs are paid today, as is the margin requirement (M) which can be viewed as a returnable deposit on the futures contract.[2] The residual (1–M) is invested for S periods at a rate r^d_S. At the end of S periods, $(1-M)\ (1+S.r^d_S)$ is returned from the deposit in addition to the initial margin M. This quantity will then be used to invest in the 90-day eurodollar futures contract which the arbitrageur takes delivery of at the end of S periods. Rearranging equation 2, the implied forward borrowing rate, F^u, is given by—

$$F^u = \frac{1}{L-S}\;\frac{(1+T)(1+L.r^b_L) - [(1-M)(1+S.r^d_S)+M]}{(1-M)(1+S.r^d_S)+M} \qquad (3)$$

By analogy, the implied forward lending rate, defining the lower arbitrage bound, F^l, is given by—

$$F^l = \frac{1}{L-S}\;\frac{(1-M)(1+L.r^d_L) - [(1+T)(1+S.r^b_S)-M]}{(1+T)(1+S.r^b_S)-M} \qquad (4)$$

No arbitrage opportunities exist if

$$F^l \leq f \leq F^u \qquad (5)$$

where f is the futures rate.

Data

The futures data used in this study are the daily closing settlement prices which are published daily by LIFFE. Since the final settlement price for any contract was, until 4 October 1984, 0.25 above the average offered price in the cash market at the time of delivery, 0.25 has been subtracted from the published series for the period before that date to produce a series for market prices. These are in turn converted to an interest rate basis by substracting from 100. Commission on the futures market is assumed to be £30, and to be paid when the futures contract is purchased. Margin on the futures contract was \$2,000 until 20 April 1983 and \$1,000 thereafter.

A bid-offer spread of ¼% per annum is chosen for eurodollar funds, as representative of the spread which a non-prime banking name would face. A prime name would face a narrower spread; thus for some market participants the arbitrage bounds would be closer together than those calculated in this article. A linear yield curve was interpolated daily between the 360, 180, 90, 60, 30 and 7 day spot rates to obtain the necessary intermediate rates for constructing daily implied forward rates. Lyons (1985) criticises interpolation because arbitrageurs may be able to police quoted market rates only for the aforementioned unbroken dates. But arbitrageurs are understood in practice to police broken dates by interpolation and to conduct business for broken dates on such a basis. This study compares futures and implied forward rates for up to 270 days ahead. Therefore, only the three futures contracts closest to delivery at any time are examined.

(1) The mechanics of the eurodollar market justify the use of simple rather than compound interest. For eurodollar deposits (loans) of up to 360 days, interest is received (paid) at the end of the period of the deposit (loan). Additionally, for transactions up to 360 days, quoted annual rates of interest have been calculated on a *pro rata* basis.

(2) Variation margin, which may have to be paid daily if prices move, is ignored. Its inclusion would have negligible effect on the results reported in this article.

Summary of results

Results for the period when contract listed was the:

Contract for delivery in:		third nearest to delivery			second nearest to delivery			nearest to delivery		
		n	m	t	n	m	t	n	m	t
December 1982	A							1	−0.20	2.1*(a)*
	W							46	0.05	0.5*(b)*
	C							47		
	T							47		
March 1983	A				21	−0.04	0.2	5	−0.16	1.0
	W				26	0.48	1.9	57	0.12	1.0*(b)*
	C				34			62		
	T				47			62		
June 1983	A	18	0.02	0.1	4	−0.16	1.3	4	−0.12	1.7*(a)*
	W	16	0.75	4.2	58	0.38	2.4	59	0.17	1.9*(b)*
	C	24			62			63		
	T	34			62			63		
September 1983	A	17	−0.08	0.5	5	−0.10	1.2	4	−0.16	1.9*(a)*
	W	35	0.71	4.0	58	0.46	3.6	65	0.13	1.0*(b)*
	C	46			62			69		
	T	52			63			69		
December 1983	A	11	−0.09	0.8	11	−0.14	1.2	7	−0.09	1.2
	W	42	0.68	5.6	58	0.40	2.2	58	0.19	1.5*(b)*
	C	51			68			65		
	T	53			69			65		
March 1984	A	29	0.01	0.1	34	0.02	0.2	4	−0.08	1.3
	W	30	0.77	6.3	31	0.54	5.1	58	0.20	1.7*(b)*
	C	45			53			61		
	T	59			65			62		
June 1984	A	32	0.01	0.2	17	−0.05	0.6	2	−0.15	1.6
	W	33	0.77	6.9	45	0.46	4.0	54	0.12	0.8*(b)*
	C	54			58			56		
	T	65			62			56		
September 1984	A	12	−0.07	0.9	8	−0.07	1.0	5	−0.24	1.6
	W	50	0.68	6.0	48	0.45	4.2	59	0.04	0.2*(b)*
	C	61			55			62		
	T	62			56			64		
December 1984	A	19	−0.02	0.1	9	−0.18	1.2	0	−0.26	1.8*(a)*
	W	37	0.74	5.8	55	0.35	1.8*(b)*	65	0.01	0.1*(b)*
	C	46			60			65		
	T	56			64			65		
March 1985	A	6	−0.14	1.0	0	−0.31	3.2*(a)*	3	−0.19	1.6
	W	53	0.61	4.1	65	0.21	1.8*(b)*	59	0.08	0.7*(b)*
	C	55			65			62		
	T	59			65			62		
June 1985	A	0	−0.34	2.6*(a)*	0	−0.33	3.4*(a)*	3	−0.17	2.0*(a)*
	W	60	0.42	2.4	62	0.19	1.7*(b)*	59	0.11	0.9*(b)*
	C	60			62			62		
	T	60			62			62		
September 1985	A	0	−0.40	3.0*(a)*	0	−0.23	2.8*(a)*	0	−0.28	3.5*(a)*
	W	57	0.35	3.4	61	0.30	3.0	64	—	0.1*(b)*
	C	57			61			64		
	T	57			61			64		

The table records, under the columns n, the number of days on which the futures rate was:

A, above the upper arbitrage bound
W, within the arbitrage band
C, within or close to (defined as being within 0.10 of a percentage point of) the arbitrage band.
T, is the total number of observations in the block (non-trading days are excluded).

m represents:

in row A, the mean of the futures rate minus the upper arbitrage bound across all T observations (the persistent negative entries indicating that the futures rate was on average below that bound); in row W, the mean of the futures rate minus the mid-point of the arbitrage band across all T observations (the persistent positive entries indicating that the futures rate was on average above the mid-point).

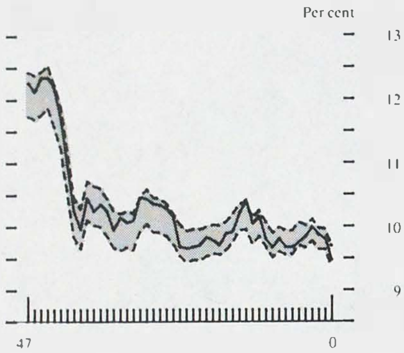
t is the t statistic relating to each m: *a* denotes instances where the futures rate is significantly (at the 95% confidence level) below the upper arbitrage bound (in no cases is it significantly above); *b* denotes instances where the futures rate is not significantly (at the 95% confidence level) different from the mid-point of the arbitrage band.

Arbitrage possibilities in the three-month eurodollar contract[a]

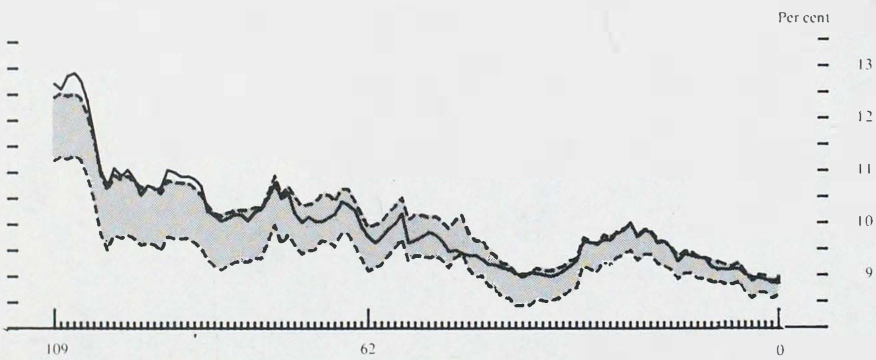
Arbitrage band

Rate on futures market

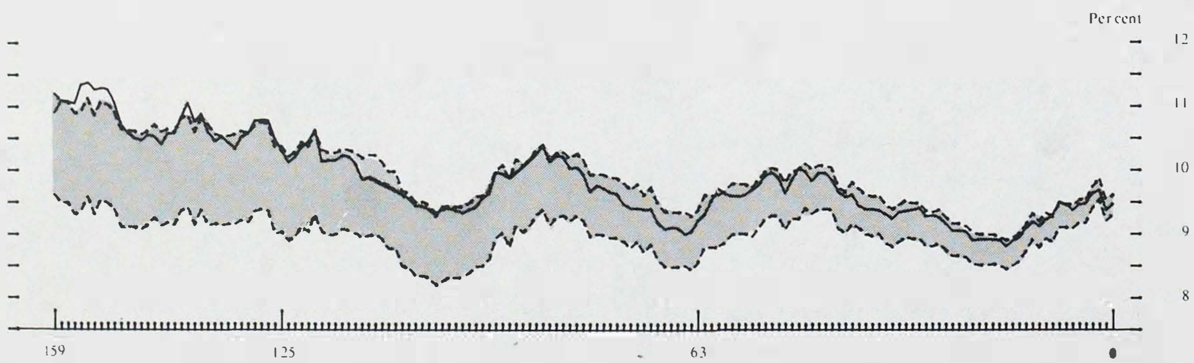
Contract to be delivered in December 1982



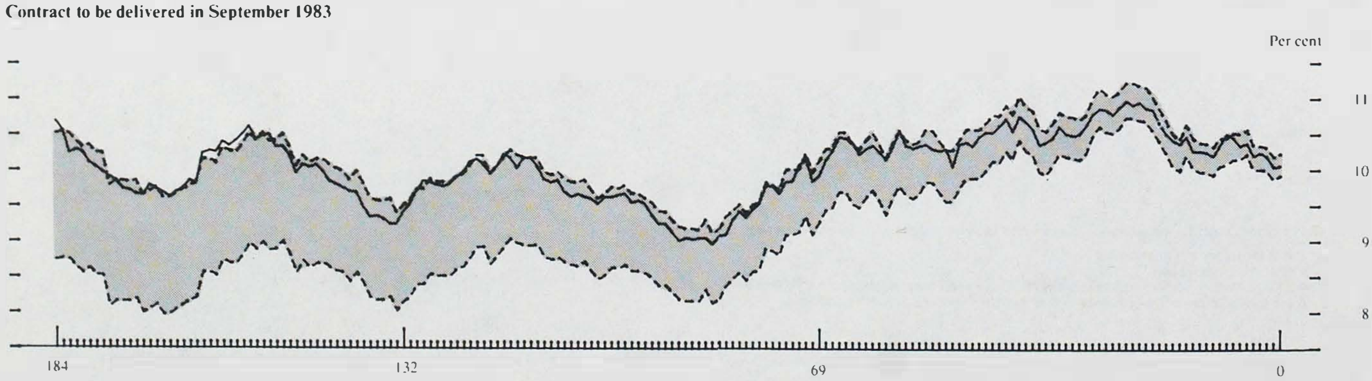
Contract to be delivered in March 1983



Contract to be delivered in June 1983



Contract to be delivered in September 1983

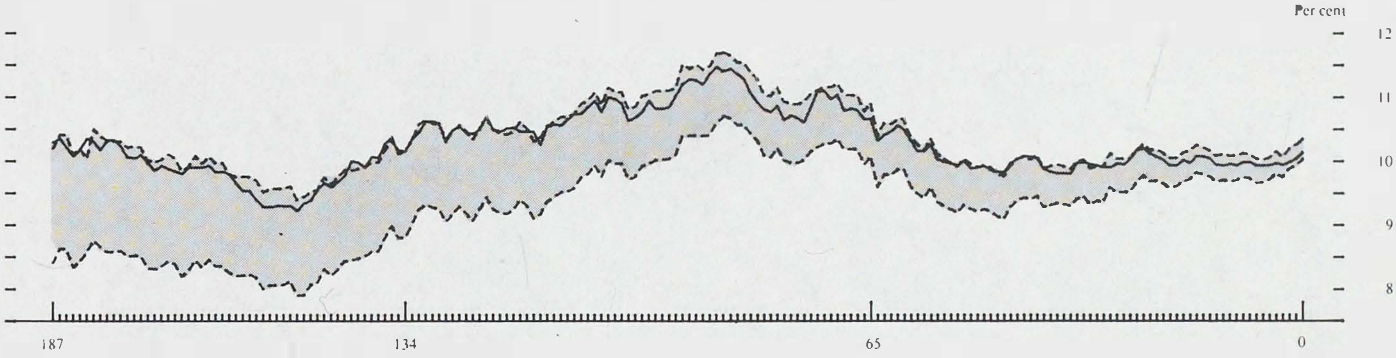


(a) The horizontal axis for each contract measures the number of working days until the last Friday before delivery, divided into three sections which represent respectively the periods during which the contract is the third nearest, second nearest and nearest to delivery. The vertical axis shows the annualised interest rate.

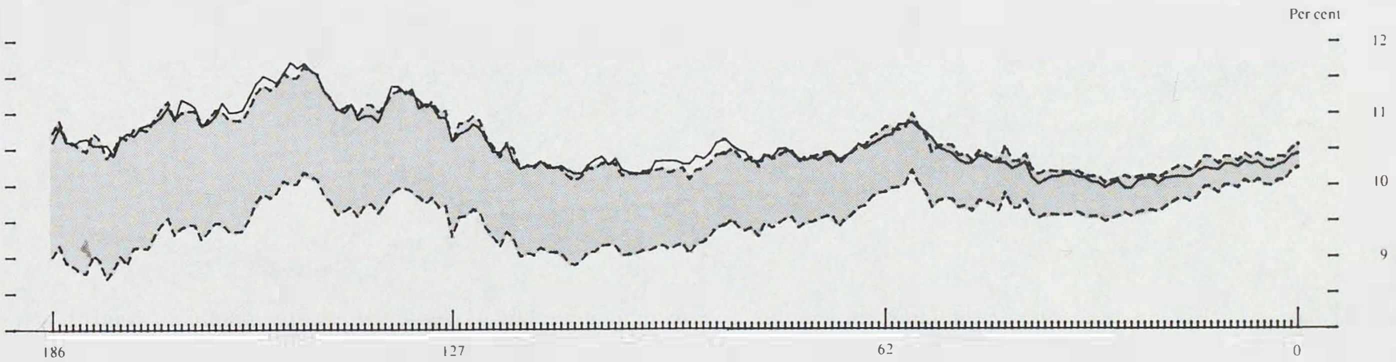
Arbitrage possibilities in the three-month eurodollar contract[a]

Arbitrage band
Rate on futures market

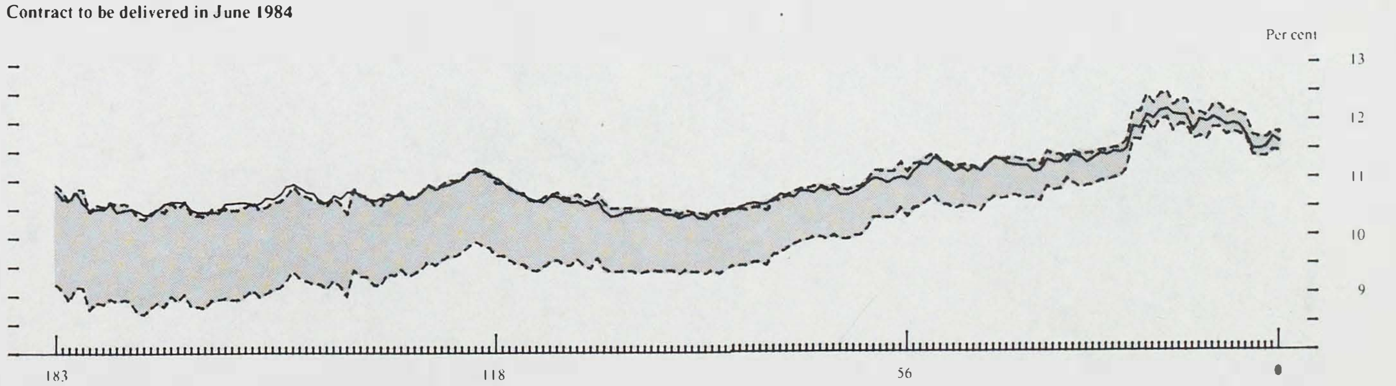
Contract to be delivered in December 1983



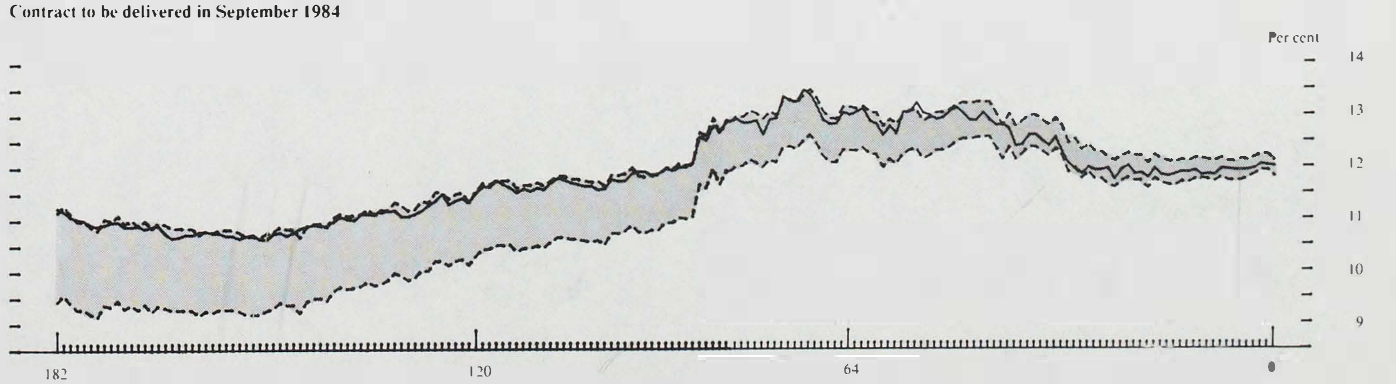
Contract to be delivered in March 1984



Contract to be delivered in June 1984



Contract to be delivered in September 1984



(a) The horizontal axis for each contract measures the number of working days until the last Friday before delivery, divided into three sections which represent respectively the periods during which the contract is the third nearest, second nearest and nearest to delivery. The vertical axis shows the annualised interest rate.

Arbitrage possibilities in the three-month eurodollar contract[a]

Arbitrage band
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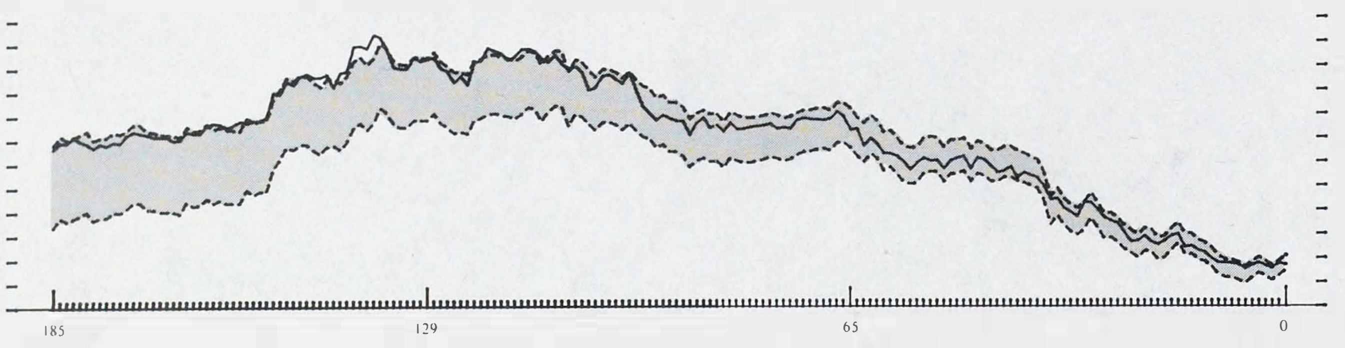
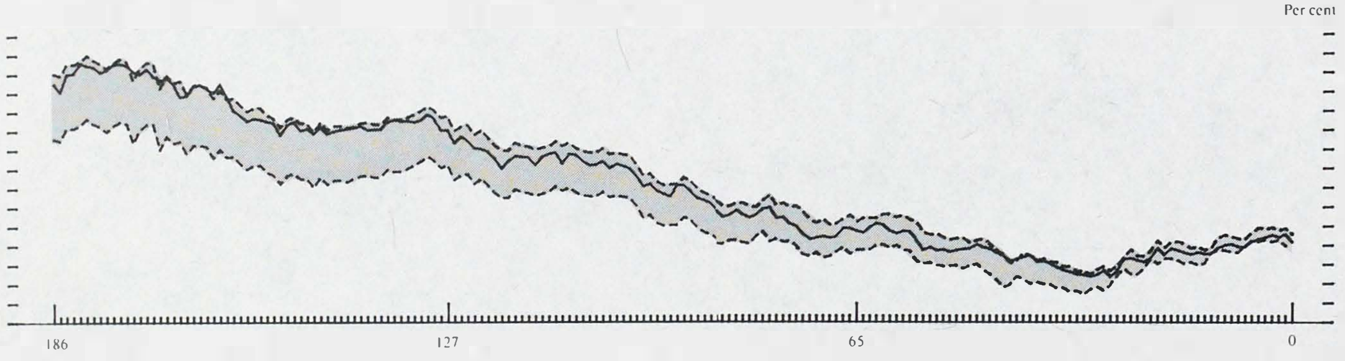
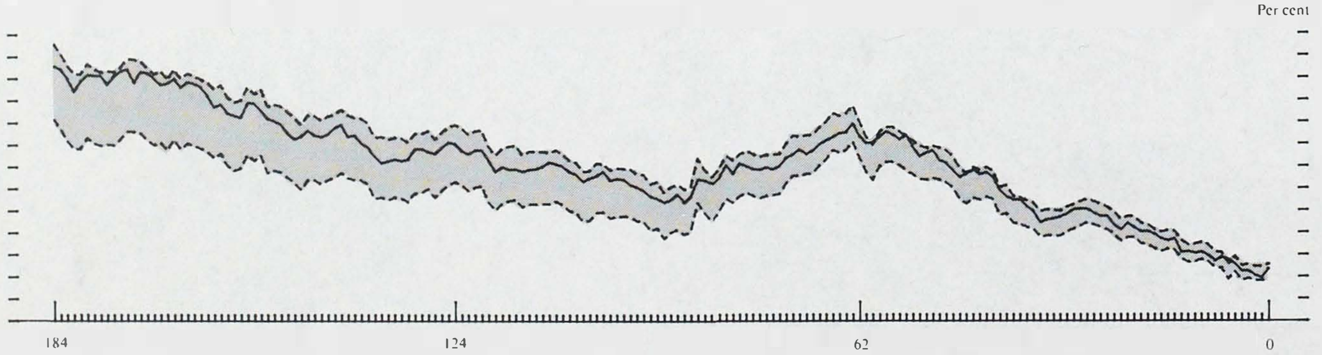
Contract to be delivered in December 1984



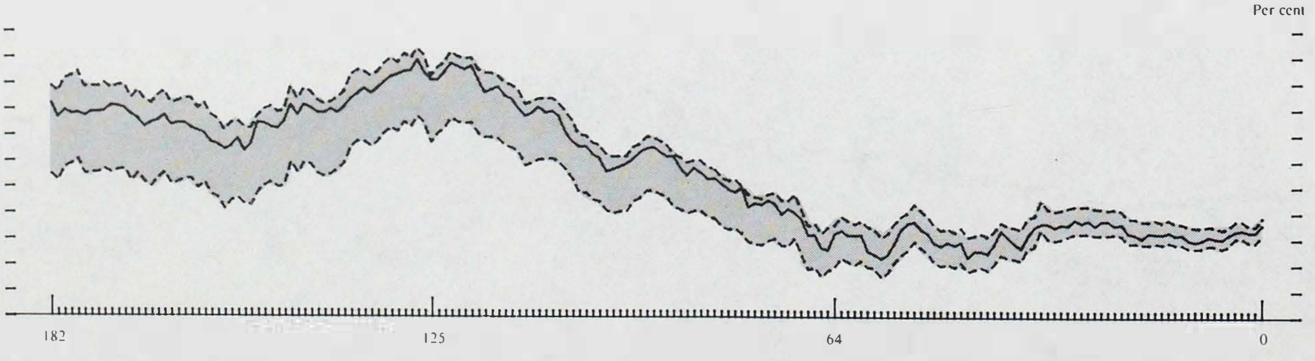
Contract to be delivered in March 1985



Contract to be delivered in June 1985



Contract to be delivered in September 1985



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